# Foundations of Modern Networking

SDN, NFV, QoE, IoT, and Cloud

By: William Stallings

# Chapter 1

Elements of Modern Networking

# 25/50 Gbps

- 25 Gigabit Ethernet Consortium
  - Includes Google and Microsoft
  - Objective is to support an industry standard, interoperable Ethernet specification that boosts the performance and slashes the interconnect cost per Gbps
  - Prescribes a single-lane 25-Gbps Ethernet and dual-lane 50 Gbps Ethernet link protocol
  - IEEE 802.3 committee is at work developing the needed standards for 25 Gbps and may include 50 Gbps

# 400 Gbps Ethernet

- IEEE 802.3 is currently exploring technology options for producing a 400-Gbps Ethernet standard
- No timetable is yet in place
- 1-Tbps (terabits per second, trillion per second) standard will eventually be produced

# 2.5/5 Gbps Ethernet

- These lower speeds are known as Multirate Gigabit BASE-T (MGBASE-T)
- Currently the MGBASE-T Alliance is overseeing the development of these standards outside of IEEE
- Mainly intended to support IEEE 802.11ac wireless traffic into a wired network
- Gaining acceptance where more than 1 Gbps of throughput is needed (such as to support mobile users in the office environment)

# Wi-Fi

- Standardized by IEEE 802.11
- Has become the dominant technology for wireless LANs
- First important use was in the home to replace Ethernet cabling for connecting desktop and laptop computers with each other and with the Internet
- Provides a cost effective way to the Internet
- Is essential to implementing the Internet of Things (IoT)

# Public Wi-Fi

Hotspots have become readily available

Remote places can support hotspots with the development of the satellite Wi-Fi hotspot

- First company to develop such a product was Iridium

The satellite modem will initially provide a relatively low-speed connection, but the data rates will inevitable increase

# Enterprise Wi-Fi

- Economic benefit of Wi-Fi is most clearly seen in the enterprise
- Approximately half of all enterprise network traffic is via Wi-Fi rather than the traditional Ethernet
- Two trends have driven the transition to a Wi-Fi centered enterprise:
  - Demand has increased with more and more employees preferring to use laptops, tablets, and smartphones to connect to the enterprise network
  - The arrival of Gigabit Ethernet allows the enterprise network to support high-speed connections to mobile devices simultaneously

# Standards

- Interoperability is essential to the success of Wi-Fi
- Wi-Fi enabled devices must be able to communicate with Wi-Fi access points regardless of the manufacturer of the device or access point
- Interoperability is guaranteed by:
  - IEEE 802.11 wireless LAN committee develops the protocol and signaling standards
  - The Wi-Fi Alliance creates test suites to clarify interoperability for commercial products that conform to various IEEE 802.11 standards
  - The term *Wi-Fi* (wireless fidelity) is used for products certified by the Alliance

# Wi-Fi Data Rates

- 802.11 (1997): 2 Mbps (megabits per second, million bits per second)
- 802.11a (1999): 54 Mbps
- 802.11b (1999): 11 Mbps
- 802.11n (1999): 600 Mbps
- 802.11g (2003): 54 Mbps
- 802.11ad (2012): 6.76 Gbps (billion bits per second)
- 802.11ac (2014): 3.2 Gbps

# 4G/5G Cellular

## First Generation 1G

- Original cellular networks
- Provided analog traffic channels and were designed to be an extension of the public switched telephone networks
- Most widely deployed system was the Advance Mobile Phone Service (AMPS) developed by AT&T
- Voice transmission was purely analog and control signals were sent over a 10-kbps analog channel

# 4G/5G Cellular

## Second Generation 2G

- Developed to provide:
  - Higher-quality signals
  - Higher data rates for support of digital services
  - Greater capacity
- Key differences:
  - Digital traffic channels
  - Encryption
  - Error detection and correction
  - Channel access

# 4G/5G Cellular

## Third Generation 3G

- Objective is to provide fairly high-speed wireless communication to support multimedia, data, and video in addition to voice
- Share the following design features:
  - Bandwidth
  - Data rate
  - Multirate

# 4G/5G Cellular

## Fourth Generation 4G

- Ultra-broadband Internet access for a variety of mobile devices, including laptops, smartphones, and tablets
- 4G networks support Mobile web access and high-bandwidth applications such as high definition mobile TV, mobile video conferencing, and gaming services
- Designed to maximize bandwidth and throughput while also maximizing spectral efficiency
- Have the following characteristics:
  - Based on an all-IP packet switched network
  - Support peak data rates
  - Dynamically share and use the network resources to support more simultaneous users per cell
  - Support smooth handovers across heterogeneous networks
  - Support high QoS for next-generation multimedia applications

# 4G/5G Cellular

## Fifth Generation 5G

- Still some years away
- By 2020 the huge amounts of data traffic generated by tablets and smartphones will be augmented by an equally huge amount of traffic from the *Internet of Things (*which includes shoes, watches, appliances, cars, thermostats, door locks, and much more)
- Focus will be on:
  - Building more intelligence into the network
  - Meeting service quality demands by dynamic use of priorities
  - Adaptive network reconfiguration
  - Other network management techniques

# Cloud Computing

- First became available in the early 2000s
- Particularly targeted at large enterprises
- Has spread to small and medium-size businesses and recently to consumers
- Apple's iCloud was launched in 2012 and had 20 million users within a week of the launch
- Evernote launched in 2008 and approached 100 million users in less than six years
- In 2014 Google announced that Google Drive had almost a quarter of a billion active users

# Cloud Computing Concepts

- The National Institute of Standards and Technology (NIST) defines the essential characteristics of cloud computing as:
  - Broad network access
  - Rapid elasticity
  - Measured service
  - On-demand self service
  - Resource pooling

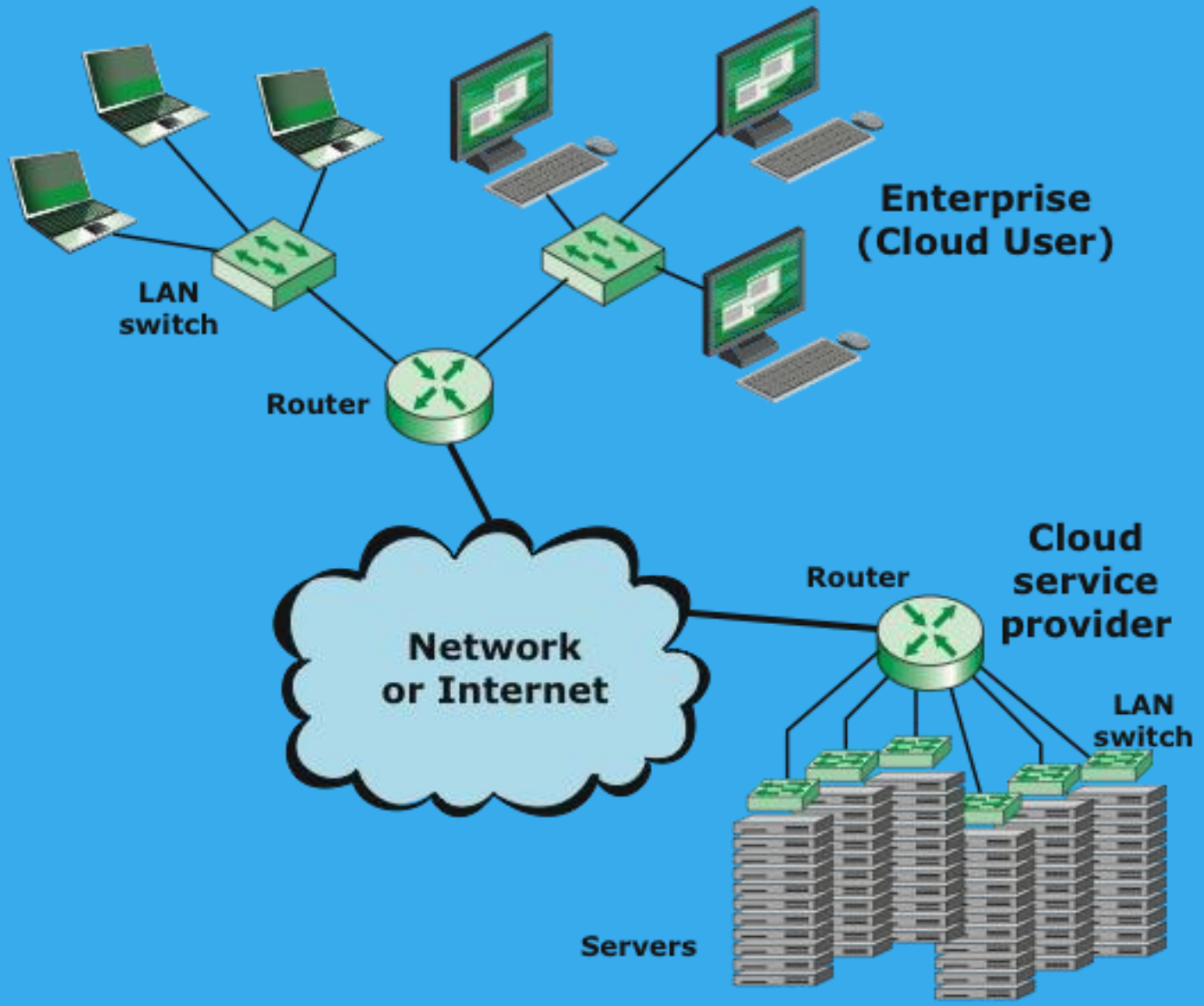


Figure 1.7 Cloud Computing Context

# Benefits of Cloud Computing

- Cloud computing provides:
  - Economies of scale
  - Professional network management
  - Professional security management
- Another big advantage of using cloud computing to store your data and share it with others is that the cloud provider takes care of security
    - Unfortunately the customer isn't always protected
    - There have been a number of security failures among cloud providers

# Cloud Networking

- Refers to the networks and network management functionality that must be in place to enable cloud computing
  - Many cloud computing solutions rely on the Internet, but that is only a piece of the networking infrastructure
- One example is the provisioning high-performance/high-reliability networking between the provider and subscriber
  - In this case, some or all of the traffic between an enterprise and the cloud bypasses the Internet and uses dedicated private network facilities owned or leased by the cloud service provider
- More generally, cloud networking refers to the collection of network capabilities required to access a cloud, including:
  - Making use of specialized services over the Internet
  - Linking enterprise data centers to a cloud
  - Using firewalls and other network security devices at critical points to enforce access security policies